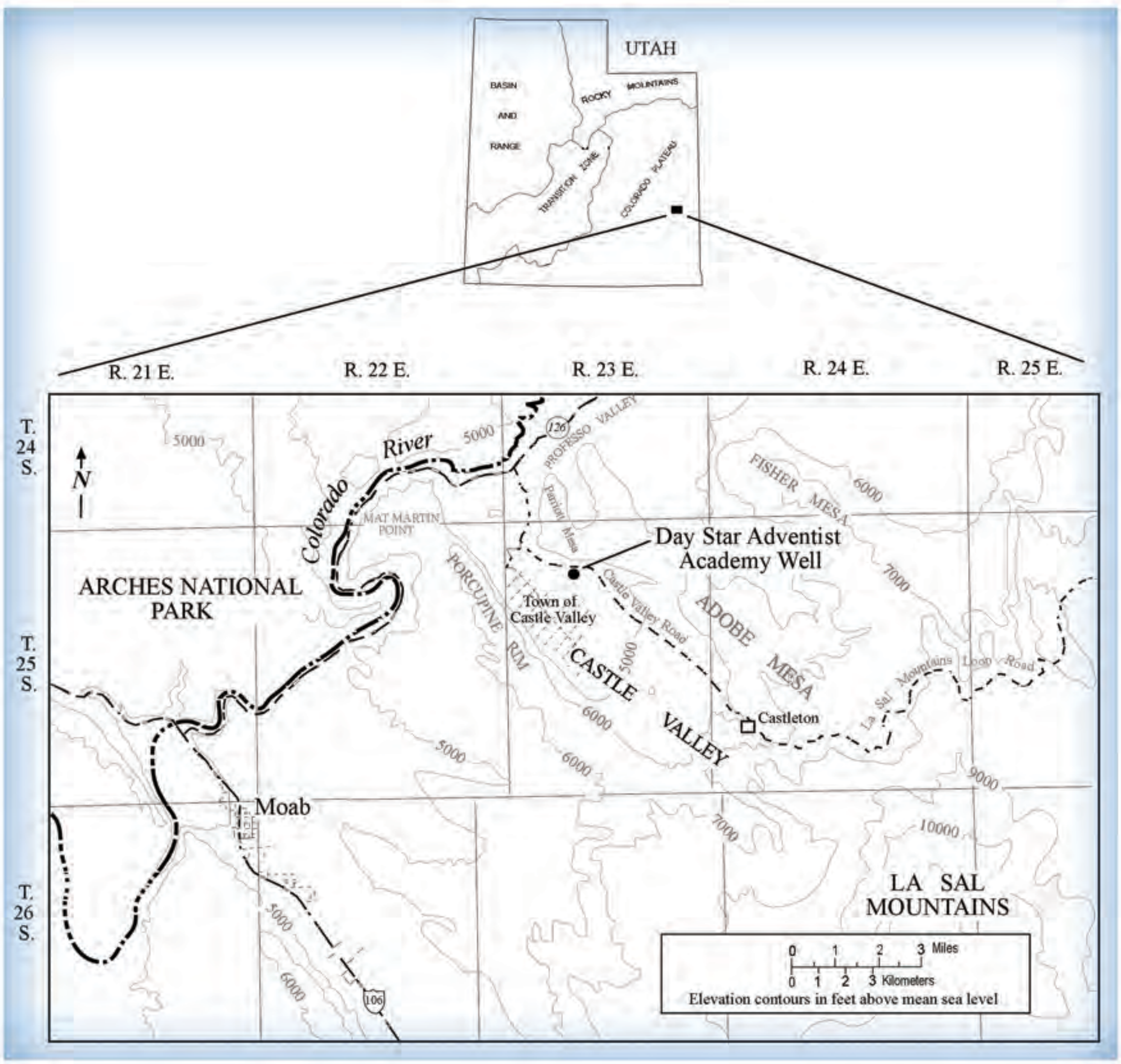
DELINEATION OF DRINKING WATER SOURCE PROTECTION ZONES FOR THE DAY STAR ADVENTIST ACADEMY PUBLIC-WATER-SUPPLY WELL, GRAND COUNTY, UTAH

by
Charles E. Bishop



REPORT OF INVESTIGATION 262
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Delineation of Drinking Water Source Protection Zones for the Day Star Adventist Academy Public-Water-Supply Well, Grand County, Utah

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ABSTRACT

The Day Star Adventist Academy operates a well to supply potable water for consumptive use by its students, staff, and facilities. The well was drilled in the mid-1950s in lower Castle Valley, Grand County, Utah. To protect this well from contamination and to comply with Utah's Drinking Water Source Protection Program, the Utah Division of Drinking Water, Department of Environmental Quality, requested that the Utah Geological Survey assist in developing the Day Star Adventist Academy Drinking Water Source Protection Plan. This report delineates the drinking water source protection zones for the Day Star Adventist Academy well.

The valley fill consists of unconsolidated Quaternary stream alluvial and alluvial-fan deposits, and is flanked by consolidated formations ranging in age from Pennsylvanian to Jurassic, with some early Tertiary igneous rocks also exposed in the area. Depth to rock can be shallow in the valley, at about 50 feet (15 m) in the area of the public-water-supply well. Eastern Castle Valley is characterized by well-exposed northwest-southeast trending faults paralleling the valley. These fault systems impact the nature and character of ground-water flow in the valley. Strata of the Permian Cutler Formation are found along and underlie the margins of Castle Valley. Examinations of rock outcrops along the eastern valley margin indicate that permeability in the clastic rocks is the result of fracturing and bedding-plane separations.

Flowing artesian wells on the northeast side of Castle Valley yield water from fractured fine-grained sandstone, siltstone, and mudstone of the Cutler Formation. Wells completed in these rocks contain confined ground water at a depth of about 210 feet (60 m) below the land surface. Ground water is recharged from the La Sal Mountains and flows toward the Colorado River, with a hydraulic gradient of about 0.008 in the area of the well. Discharge from the rock aquifer occurs by slow upward leakage to a shallow aquifer, seepage to the Colorado River, and through wells. No aquifer tests or direct estimates of the transmissivity or hydraulic conductivity of the fractured-rock aquifer were performed. Instead, estimates of hydraulic parameters were from regional data, and the results were used to define effective aquifer parameters that represent the fractured aquifer.

I used the effective hydraulic parameters determined from the hydrogeology evaluation and treated the fractured-rock aquifer as an equivalent porous medium so that individual fractures could be ignored when quantifying flow. I used a semi-analytical, steady-state, two-dimensional ground-water flow model (WHPA) to delineate the two-dimensional time-related capture zones. Time-of-travel capture zones are based on the definition of the wellhead protection zones surrounding the drinking water source. The particle-tracking algorithm used in the semi-analytical model required estimates of effective porosity, flow direction, hydraulic gradient, transmissivity, and discharge of the well to predict ground-water-flow pathlines and travel times to the well. Capture zones were generated for 250-day, three-year, and 15-year ground-water travel times. Results from the simulation indicate elongated semi-ellipse-shaped protection zones for the well. The maximum extent of the zones, under maximum discharging conditions, is approximately 5100 feet (1550 m) upgradient, 500 feet (150 m) downgradient, and 2900 feet (880 m) wide.

INTRODUCTION

This report describes the delineation of drinking water source protection (DWSP) zones for a public-water-supply well (Utah Division of Drinking Water system number 10012, source number 01) in the NE¼NE¼NW¼ section 8, T. 25 S., R. 23 E., Salt Lake Base Line and Meridian (SLB&M), in Castle Valley, eastern Grand County, Utah (figure 1). Castle Valley contains the towns of Castle Valley and Castleton, an agricultural industry, and in the northeastern part of the valley the Day Star Adventist Academy (the Academy). The Academy is a school and farming operation that uses the well to supply water for students, staff, and facility operations. The Utah Division of Drinking Water requested, and the Academy assisted in, this delineation of DWSP zones. The scope of work included a literature search, reviews of water-well logs, field reconnaissance, evaluation of aquifer data, delineation of the DWSP zones, and preparation of this report.

Utah's Drinking Water Source Protection Rule (R309-600, Utah Administrative Code; administered by the Utah Division of Drinking Water) requires public-water suppliers in Utah to develop a DWSP plan for each well or spring used as a public-drinking source. The delineation of DWSP zones around public-water supplies is a major component of the DWSP plan, and part of a preventive strategy to minimize potential degradation of water quality by defining areas providing water over specific time intervals to wells. This strategy creates a limited area to concentrate resources for inven-

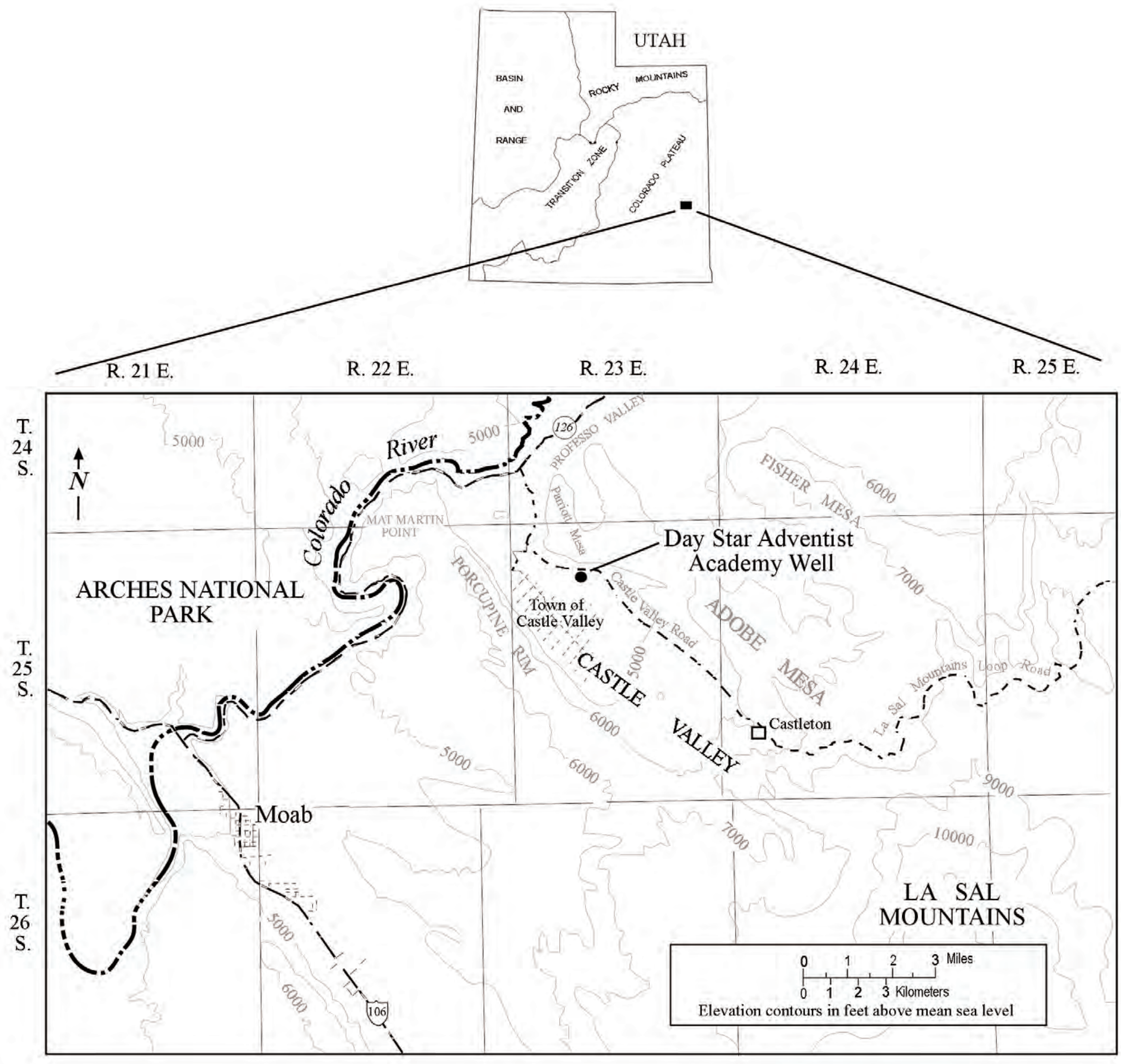

Figure 1. Location of the Day Star Adventist Academy well, Grand County, Utah.

tory, control, and monitoring with an overall goal of assuring the quality of public-water supplies. Local governments can then implement land-use regulations to protect and reduce the risk of future ground-water contamination and costly remediation efforts in these areas. Utah's DWSP Rule (R309-600-9 [3]) defines four DWSP zones:

Zone 1 - the area within a 100-foot (30 m) radius from the wellhead;

Zone 2 - the area within a 250-day ground-water time-of-travel to the wellhead, the boundary of the aquifer(s) that supplies water to the well, or the ground-water divide, whichever is closer to the well;

Zone 3 - (waiver zone) - the area within a three-year ground-water time-of-travel to the wellhead, the boundary of the aquifer(s) that supplies water to the well, or the ground-water divide, whichever is closer to the well; and

Zone 4 - the area within a 15-year ground-water time-of-travel to the wellhead, the boundary of the aquifer(s) that supplies water to the well, or the ground-water divide, whichever is closer to the well.

The DWSP Rules require the delineation of zones 1, 2, and 4. A waiver zone, zone 3, is included to help the water supplier with future monitoring waivers (see R600-9 [3][iii]).

To delineate DWSP zones one of two procedures may be used: (1) a "Preferred Delineation Procedure" based on ground-water times of travel and local geology and hydrogeology, or (2) an "Optional Two-Mile Radius Delineation Procedure" based on identifying all upgradient areas supplying water to a well or spring within a fixed 2-mile (3.2 km) radius of the drinking-water source. I delineated the DWSP zones for the Academy well using the "Preferred Delineation Procedure" because it reflects the hydrogeologic system and is more defendable than the other procedure.

In this study, I delineated DWSP zones 2, 3, and 4. Zone 1, a 100-foot (30 m) fixed radius around the well, is not shown on the map or discussed further in this report.

GEOLOGY

The Academy's public-water-supply well is within the Salt Anticline segment of the Colorado Plateau physiographic province (Stokes, 1977). In this area, landforms are related to the subsurface movement of salt layers in the Pennsylvanian Paradox Formation. As salt layers were buried by younger sediments, they became mobile and formed diapirs that folded overlying rocks into anticlines. The uplift of the Colorado Plateau in the late Tertiary resulted in high rates of erosion, allowing ground and surface water to contact and dissolve the salt layers from the cores of the anticlines (Mulvey, 1992; Doelling and Ross, 1998). Subsequently, the overlying rock strata collapsed and eroded, forming an inverted topography in the core of the anticlines. High-angle normal fault systems, developed as a result of the collapse of the salt diapir, are present along the margins of Castle Valley (Doelling and Ross, 1998).

Pennsylvanian to Jurassic sedimentary rocks are exposed in lower Castle Valley (figure 2). Isolated interbedded evaporates, clastic, and carbonate rocks of the Pennsylvanian Paradox Formation are exposed at the northwestern end of Castle Valley (Doelling and Ross, 1998; Doelling, 2001). Quartz arenite and subarkosic to arkosic sandstone interbedded with conglomerate, silty and sandy mudstone, and siltstone make up the Permian Cutler Formation, which underlies the valley and crops out in the lower cliffs of its northern margin (Doelling and Ross, 1998; Doelling, 2001) (figures 2 and 3). Triassic sandstone, siltstone, and mudstone of the Moenkopi and Chinle Formations overlie the Cutler Formation and form the intermediate cliffs in the valley. Jurassic sandstone, siltstone, and mudstone of the Wingate and Kayenta Formations form the high cliffs along the sides of the valley. Tertiary igneous rocks composed largely of Oligocene intrusive rocks, mainly porphyritic trachyte, are exposed at Round Mountain in the center of Castle Valley, and in the La Sal Mountains (Doelling, 2001) south of the area shown in figure 2.

Faults along the northeast flank of Castle Valley are well exposed in the Moenkopi Formation, above the Cutler Formation, and northeast of the well. The faults cut the rocks into narrow fault-bounded strands paralleling the valley. The outermost fault trends N. 65° W. and dips valleyward 70° SW. The fault displaces strata 60 to 70 feet (18–21 m) (Doelling and Ross, 1998). Fault traces can be projected below unconsolidated deposits southeastward into the area of the Academy. Fault-bounded strands of the Cutler Formation most likely underlie the margins of Castle Valley, and strands of the Jurassic, Triassic, Permian, and possibly Pennsylvanian rocks may underlie Quaternary valley-fill deposits in the center of Castle Valley (figure 3).

Outcrops of the Cutler Formation appear as red-brown, red-purple, orange, and maroon rocks that form near vertical cliffs to alternating ledges and slopes with step-like escarpments. Sandstones are generally subangular to subrounded, fine grained, poorly to well sorted, and micaceous. Bedding plane separations and fractures, important secondary permeability features in a bedrock aquifer, are visible in sandstone and siltstone outcrops about 0.7 mile (1 km) east of the well. Bedding plane spacing ranges from 1 to 12 inches (2–30 cm). The bedding at the outcrops strikes N. 50° W. and dips 7° NE. One set of fractures trends roughly N. 45° E., dips 66° S, and has a fracture spacing ranging from 5 to 14 inches (13–36 cm). The other set strikes roughly N. 27° W., dips 85° W., and has a fracture spacing of 4 inches to 3 feet (10–90 cm).

The valley fill of Castle Valley consists predominantly of gravelly stream alluvium and alluvial-fan deposits that are generally coarser grained near source areas at the base of Porcupine Rim and the La Sal Mountains, and finer grained along the lower reaches of Castle Creek (Snyder, 1996; Doelling and Ross, 1998). The thickness of alluvial-fan deposits along the valley margins is highly irregular, and may locally exceed 25 feet (8 m) or thin to zero. Numerous buried rock ridges and small, deep troughs affect the thickness of unconsolidated valley-fill deposits in Castle Valley. Unconsolidated deposits are generally less than 150 feet (50 m) thick but vary to over 350 feet (100 m) in parts of sections 8, 9, and 15, T. 25 S., R. 23 E., SLB&M, below Castle Creek, and to 250 feet (80 m) below the central part of the valley (Lowe and others, 2004).

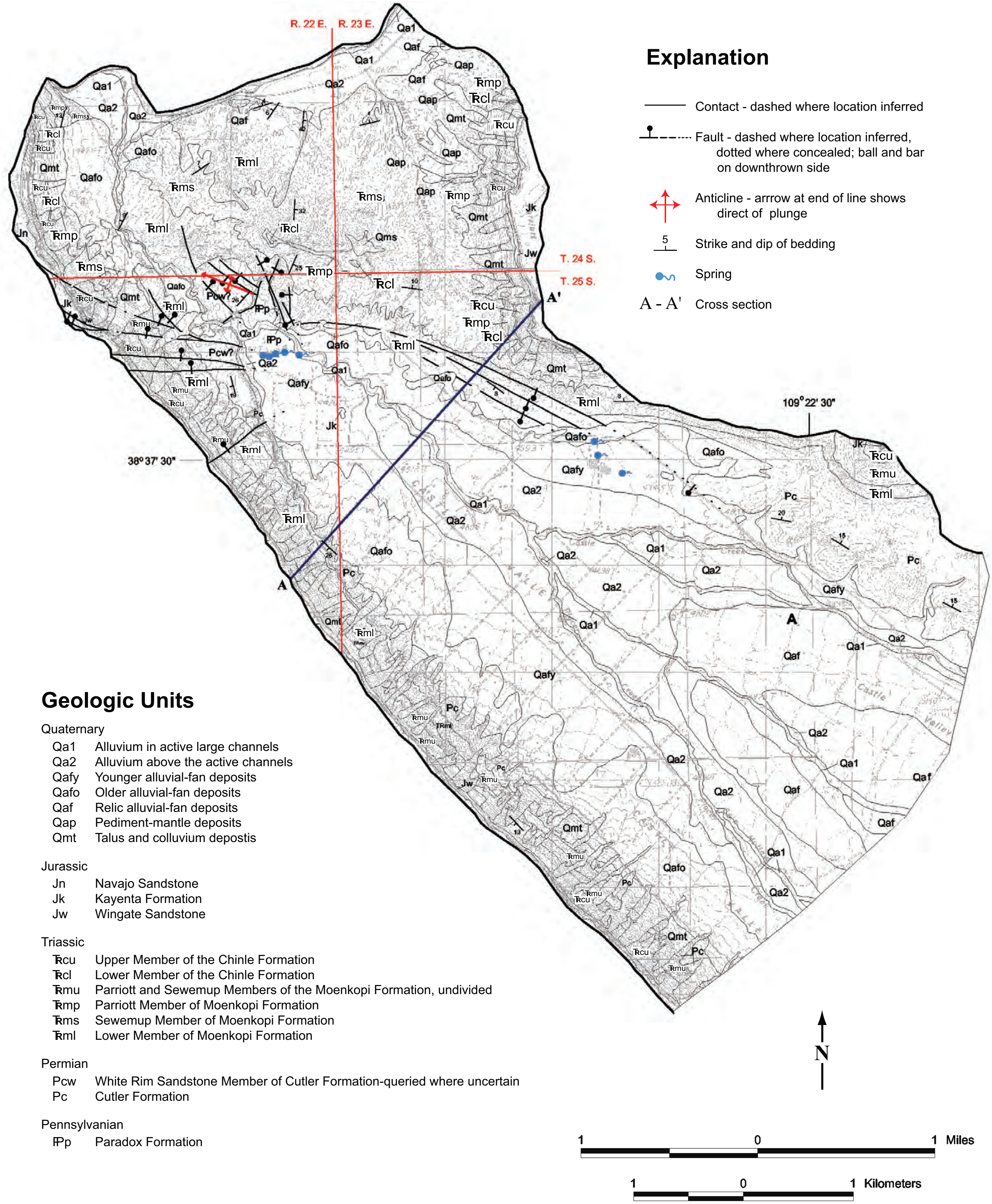

Figure 2. *Geologic map of the lower Castle Valley area (modified from Doelling and Ross, 1998).*

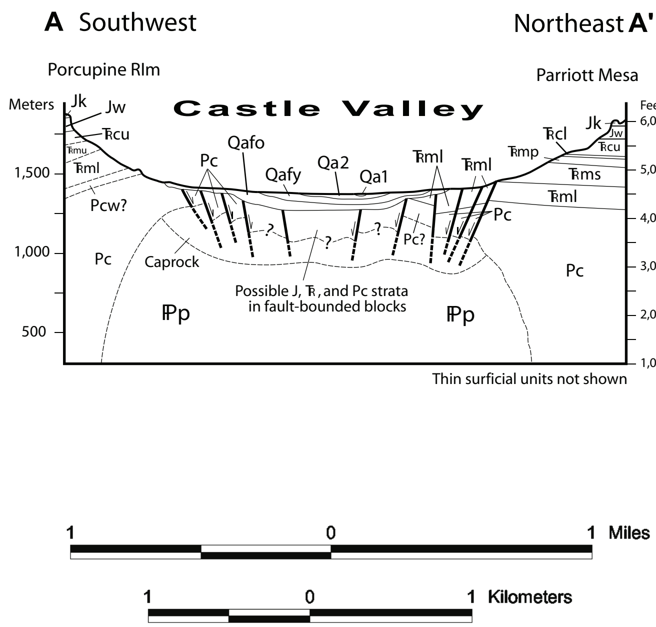

Figure 3. *Schematic geologic cross section across lower Castle Valley. See figure 2 for location and explanation of geologic units (modified from Doelling and Ross, 1998).*

HYDROGEOLOGY

Ground water in northeastern Castle Valley is confined in fractured rock beneath relatively impermeable rock, or is unconfined in fine-grained unconsolidated surface materials. Hydrogeologic conditions in the fractured-rock aquifer are inferred from a few lithologic descriptions of wells and the examination of outcrops. These data are interpreted to define the hydrostratigraphy, depth to producing strata, and the quantity of water produced by the artesian zone. Descriptions of the lithology of the unconsolidated valley-fill aquifer system are given in Snyder (1996) and Blanchard (1990). However, very little data are given on the fractured-rock aquifer in either of these reports.

Pervious rocks below the unconsolidated valley-fill deposits of Castle Valley contain ground water with a hydrostatic (pressure) head different from the hydrostatic head of the unconfined, unconsolidated valley-fill aquifer above. The fractured-rock aquifer consists of dipping, layered fractured rocks with ground-water flow primarily along fractures and bedding planes. Vertical fractures generally do not cut extensively across beds, but may provide local routes of ground-water flow or leakage between beds. The fracture systems in northeastern Castle Valley are isolated in packages by the local faults of the area, which control the overall direction of ground-water flow. The upper part of the Cutler Formation is the main fractured-rock aquifer currently used in Castle Valley. Rocks stratigraphically above the water-producing rocks appear to be of significantly lower permeability and are less fractured than the water-producing strata; this may result in transmissivity differences of three or four orders of magnitude.

Blanchard (1990) reported that approximately 30 wells receive water from the bedrock aquifer in western Castle Valley, but provided little information about the wells. The number of wells completed in bedrock has probably increased slightly since his report. Wells producing from the bedrock aquifer in western Castle Valley are not flowing artesian wells, unlike the fractured-rock wells to the east discussed above, but water levels do rise above the confining layer. Fractured-rock aquifer wells in western Castle Valley are generally less productive than the wells to the east (possibly indicating that the two sides of the valley are not directly connected hydrologically).

Recharge to the fractured-rock aquifer underlying the Academy is from downward percolation of precipitation along fractures on exposed rocks, and from streams that cross the outcrops in the La Sal Mountains. The La Sal Mountains are an intrusive complex with upturned sedimentary strata along its flanks that are favorable for recharge. The La Sal Mountains reach elevations above 9000 feet (2800 m) and can receive more than 30 inches (76 cm) of precipitation per year. The upturned and heavily fractured sedimentary strata comprising the flanks of the La Sal Mountains are at the surface, or commonly less than 20 feet (6 m) below the land surface in the recharge area. The high mountain slopes are mantled in many areas by talus, which readily absorbs snowmelt runoff and precipitation and releases the water to the rock below (Blanchard, 1990). After infiltration directly through weathered rock or thin unconsolidated materials, the water moves down the dip of the strata through fractures, beneath overlying confining beds, and toward areas of natural discharge. The hydraulic head in the rock aquifer is due to the high elevation of the recharge area. Discharge is from: (1) consumptive use for irrigation and domestic purposes, from springs and wells; (2) evapotranspiration in the higher parts of Castle Valley; and (3) underflow to the Colorado River.

The geology and topographic relief of the area limit the areal extent of the ground-water flow system in Castle Valley. The fractured-rock aquifer in Castle Valley is delimited by faults and is localized into fault-bounded strands of rock, with varying degrees of hydraulic connection between strands. Individual strands may be bounded by less fractured rock, surface- and ground-water divides, or the Colorado River. The high relief of the mountains and low relief of the valley cause a funneling of ground water through the valley.

The hydraulic head in the fractured-rock aquifer decreases from the area of recharge toward the Colorado River, and the direction of flow in the aquifer is approximately northwest. In the lower parts of the valley the hydrostatic head is sufficient to lift the water above the land surface. The potentiometric surface for the fractured-rock aquifer is above the land surface in the area of the Academy, and wells are flowing artesian wells. I could not map the potentiometric surface of the fractured-rock aquifer because of the sparse information about the wells that reach it; however, there are water-level data for numerous wells penetrating the valley-fill aquifer. Water-level data collected by Snyder (1996) from wells throughout the valley completed in the valley-fill aquifer were used to construct a map of the potentiometric surface of that aquifer (figure 4). The water-level data indicate that the hydraulic gradient varies from 0.01 to 0.06 for the valley-fill aquifer. Like the valley-fill aquifer, hydrostatic head in the fractured-rock aquifer is reduced as water moves through the rocks; the hydrostatic head diminishes gradually from the recharge area in the south to the discharge area in the north. I conclude that the gradient in the fracture-rock aquifer will be less than that in the valley-fill aquifer, because the slope of the rocks down valley is flatter. I estimated the horizontal hydraulic gradient of the rock aquifer to range from 0.01 to 0.006, and it is probably about 0.008 in the area of the Academy well.

WELLS

There is no record of the first well drilled in Castle Valley, but the earliest wells were probably within rock in the Castleton area, as the unconsolidated valley fill in this area is thin. Well depths in the valley fill range from 58 to 248 feet (18–76 m) and are typically less than 150 feet (45 m) deep. Wells completed in rock are typically 150 to 300 feet (45–90 m) deep, and on the east side of the valley are artesian (Snyder, 1996). The first artesian well drilled in bedrock beneath the valley was reportedly drilled for mineral exploration in the early 1950s (John Korponay, Academy water system manager, verbal communication, March 1999). There is some speculation that the Academy wells were originally drilled for mineral exploration, but the size of most of the wells indicates they were agricultural wells. The flowing artesian wells in the area of the Academy were drilled in the mid-1950s (appendix A).

The Academy public-water-supply well is located in a 16-foot by 7-foot (5 x 2 m) block and frame building. Two flowing artesian wells are in this building (about 5 feet [2 m] apart). Only one of the wells is used as a drinking water source. A pump on the building floor is used to lift water from the public-water-supply well (one of the artesian wells) to a storage tank, which is about 170 feet (50 m) east-southeast, and 7 feet (2 m) above the well. Water from the other well is used for irrigation. Based on the driller reports, the Academy well is drawing water from fractured rock below about 210 feet (60 m). I estimate the aquifer thickness that contributes to the well to be 80 feet (24 m). My examination of the public-water-supply well indicated determining a true shut-in pressure was not possible, because the well was not set up to measure pressure, and the continuous demand for the water precludes the practicability of shutting in the well. During the present investigation, the public-water-supply well was estimated to have a maximum head above the well casing of 3 feet (1 m), and the flow under normal operating conditions was estimated to be a persistent 10 to 15 gallons per minute (0.04–0.06 m^3/min) (John Korponay, verbal communication, March 1999). Weir and others (1983) reported the average flow from bedrock wells in the area is about 5 gallons per minute (0.02 m^3/min). The well possibly discharged from 100 to 200 gallons per minute (0.4–0.8 m^3/min) when drilled in the mid 1950s.

How the Academy well is completed is not clear from driller reports. Apparently the well was started with a cable drill, to drill through the alluvium, and then deepened into the bedrock by a rotary drill. The well is cased through unconsolidated valley-fill and open in the bedrock, and is probably about 300 feet (90 m) deep (John Korponay, verbal communication, March 1999). The proof of beneficial use was not completed at the time it was drilled and the application to appropriate water from the well was allowed to lapse. The water rights for the well were not proven until the early 1970s. The water records are incomplete, and I could not identify which water well report belongs to the Academy public-water-supply well, so I evaluated all well reports for wells drilled in the early- to mid-1950s within a mile of the Academy well (appendix A).

AQUIFER CHARACTERISTICS

Driller reports for the flowing artesian wells and geological mapping in northeastern Castle Valley indicate wells produce from fractured rock of the lower Cutler Formation. The lower Cutler Formation consists of fine-grained subarkosic to arkosic sandstone with interbedded mudstone and siltstone. An examination of Cutler Formation outcrops near the Academy indicated permeability in the clastic strata is predominantly secondary and the result of local fracturing and bedding-plane separations. Fracture intensity is areally diverse, even at shallow depths, indicated by shallow low-transmissivity intervals designated on well logs and from outcrop examinations. Cementing material has reduced the primary porosity, permeability, and storage in the rocks of the area. Rock aquifer porosity can be described in terms of total porosity, the volume of water contained within a volume of rock, or, in terms of effective porosity, the volume of water contained within the rock fractures. The latter is water that moves readily in response to an imposed hydraulic gradient. I estimated the ranges of porosity in the sandstone and finer grained rocks to range from 1 to 30 percent and in the water-

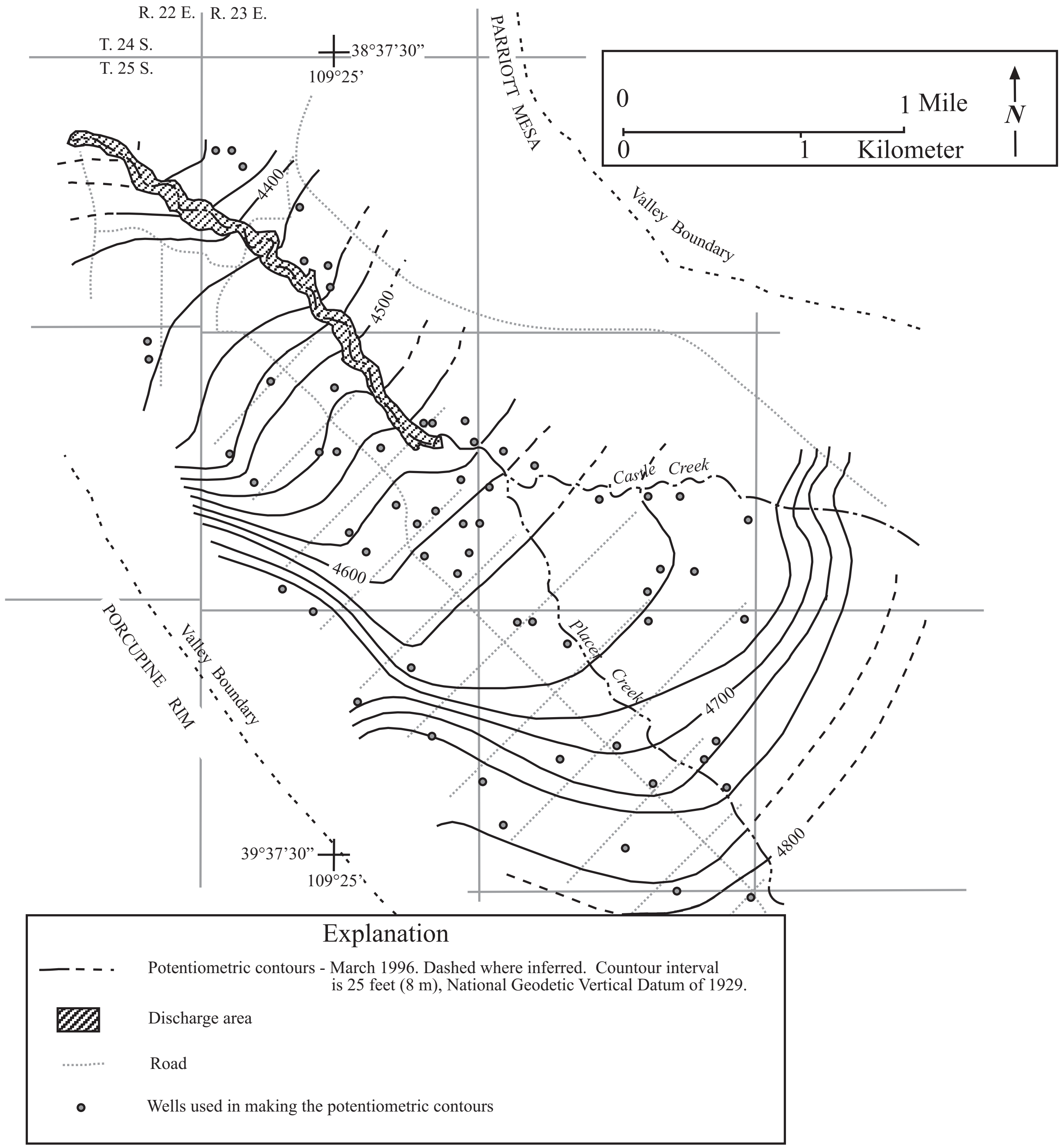

Figure 4. *Potentiometric-surface map in the valley-fill aquifer of northern Castle Valley, also showing discharge area (from Snyder, 1996).*

producing rocks to range from 13 to 17 percent.

No aquifer tests were conducted to estimate the transmissivity or hydraulic conductivity of the fractured-rock aquifer in Castle Valley. No data are provided on the driller reports that can be used to calculate transmissivity of the aquifer. Estimates of transmissivity and hydraulic conductivity in the rock aquifers of the area are rarely obtained, because few wells are actually drilled in rock aquifers, drillers usually are not equipped to perform aquifer test in rock aquifers, and the drilling of multiple well groups that can be used for aquifer tests is even less common. Aquifer tests conducted in rocks throughout Grand County, including unfractured to highly fractured rock, yielded values of hydraulic conductivity ranging from 0.0037 to 88 feet per day (0.0011–27 m/day) and transmissivities ranging from 40 to 700 square feet per day (4–65 m^2/day) (Eisinger and Lowe, 1999). Jobin (1962) estimated transmissivity of Upper Permian sandstone in this area of the Colorado Plateau to range from about 150 to 1000 square feet per day (14–93 m^2/day). Walton (1991) estimated transmissivity of fractured sedimentary rock in the Colorado Plateau to range from about 5 to 1000 square feet per day (1–93 m^2/day). Teller and Chafin (1986) used a drill-stem test on a Permian sandstone in this area of the Colorado Plateau to estimate a hydraulic conductivity of 0.02 feet per day (0.006 m/day). Freeze and Cherry (1979) and Domenico and Schwartz (1990) estimated the hydraulic conductivity of sedimentary rocks similar to the rocks found in the study area to range from 0.0001 to 1 foot per day (0.00003–0.3 m/day), and 0.0001 to 1.7 feet per day (0.00003–0.5 m/day), respectively. These and other data are tabulated in table 1 and give a range of hydraulic parameters that might be expected in Castle Valley. I used the data in table 1 to estimate conservatively the transmissivity of the aquifer supplying the Academy well.

DWSP ZONES

Many critical problems exist regarding the delineation of DWSP zones for fractured-rock aquifers. The complex hydrogeology of such aquifers makes determining ground-water time-of-travel for delineation of DWSP zones difficult. I attempted to model the ground-water system around the well using a finite-difference model, but because of limited and insufficient field data, and the complex nature of the ground-water-flow system, I could not build or calibrate an adequate finite-difference model. Instead, available semi-analytical techniques were considered sufficient for the representation; I simulated the ground-water-flow system using estimates of effective hydraulic parameters and treated the system as an equivalent porous media. The advantage of treating fractured rock as an equivalent porous media is that individual fractures can be ignored when quantifying flow. In applying the porous media assumption, the scale of the model is assumed sufficiently large that local heterogeneities do not need explicit representation, and spatially averaged effective parameters adequately represent rock properties. I used conservative effective hydraulic parameter values, such as transmissivity, in the semi-analytical model. These effective hydraulic parameter are generally representative of aquifer conditions, and account for the uncertainties inherent in the equivalent porous media approach.

I delineated DWSP zones 2, 3, and 4 for the well based on site-specific hydrogeologic data, effective aquifer parameters, and application of the RESSQC module of WHPA. WHPA is a two-dimensional semi-analytical ground-water-flow model published by the U.S. Environmental Protection Agency. The RESSQC module delineates two-dimensional time-related capture zones for wells in an aquifer of infinite aerial extent with steady-state ground-water flow (Blandford

Table 1. *Range of transmissivities and hydraulic conductivities reported for rock aquifers.*

Data Type	Transmissivity ft^2/day	Hydraulic Conductivity ft/day	Source of Data
Aquifer test	40 to 700	0.0037 in unfractured to 88 in highly fractured sandstone	Eisinger and Lowe (1999)
Plug analysis	150 to 1000	-	Jobin (1962)
Drill stem tests	-	0.02	Teller and Chafin (1986)
Generalized data for fractured sedimentary rock with a soil cover	5 to 1000	0.01 to 8	Walton (1991)
Generalized data for sedimentary rock	-	0.0001 to 1	Freeze and Cherry (1979)
Generalized data for sedimentary rock	-	0.0001 to 2	Domenico and Schwartz (1990)

and Huyakorn, 1991). Capture zones are based on the volume of aquifer supplying water to a well at a specified flow rate for a given time. Particle tracking in the RESSQC module is based on Darcy's law for water flowing through a porous medium. The semi-analytical model requires estimates of the hydraulic gradient orientation and magnitude, effective transmissivity, effective porosity, and thickness of the aquifer.

The transmissivity of a fractured-rock aquifer is a function of two physical characteristics of the rocks: fractures and their orientation, and interconnected porosity. Ground-water travel times based on the estimated transmissivity value may be different from the actual travel time in the fractured aquifer system due to aquifer heterogeneity. To adjust the transmissivity value to account for aquifer heterogeneity, I defined an "apparent" effective transmissivity as the estimated effective transmissivity in the dominant direction of ground-water flow. In this context and in accordance with estimated values of hydraulic parameters, I used an effective transmissivity of 1000 square feet per day (90 m^2/day), the maximum transmissivity reported in table 1. Ground-water flow in the aquifer is influenced by the orientation of fractures and faults in the rock. The major structural features of the area trend roughly S. 65° W. These features appear to affect local ground-water flow as determined by the higher water production from, and hydraulic heads in the rock aquifer on the east side of the valley. I used this orientation as the dominant direction of ground-water flow and assigned a uniform hydraulic gradient of roughly 0.008 from my analysis of the hydraulic gradient. A flow rate of 38,600 cubic feet per day (1100 m^3/day), based on reported flow rates for fractured-rock aquifer wells in the area, was assumed in computing the capture zone for the well. This value is representative of the well site under a gradient that was typical of heads when the well was drilled. I assumed that the aquifer had an effective porosity as high as 15 percent because the reported high flow rates from the aquifer indicate reservoir-quality transmissive properties. In table 2 the input parameters to the WHPA model are summarized.

DWSP zones 2, 3, and 4 for the well are shown on figure 5. The relatively large flow rate and transmissivity, and moderate ground-water flow gradients at the well site lead to elongated oval-shaped capture zones. The boundaries of all protection zones extend out from the well with an elongation to the southeast (upgradient of the well). Maximum distances and widths from the well for zones 2, 3, and 4, as well as protection zone orientations, are given in table 3.

Table 2. *Inputs to WHPA model for the Day Star Adventist Academy well.*

Parameter	Value	Source
Number of flowing wells	1	This report
Transmissivity	1000 ft^2/day	This report
Aquifer thickness	80 ft	Part of uncased interval on driller's log, this report
Aquifer Effective Porosity	0.15 (dimensionless)	Driller's log, this report
Average Hydraulic Gradient	0.008 (dimensionless)	Based on unconfined aquifer water levels, and land surface topography, this report
Direction of Gradient	S. 65° W.	Based on geology, this report
Flow Rate	38,600 ft^3/day	Driller's reports
Well radius	0.5 ft	This report

Table 3. *Description of DWSP zones 2, 3, and 4 for the Day Star Adventist Academy well.*

	Zone 2	**Zone 3**	**Zone 4**
Maximum upgradient distance	600 ft (180 m)	1600 ft (490 m)	5100 ft (1600 m)
Orientation (from well) of maximum upgradient distance	S. 32 E.	S. 47 E.	S. 57 E.
Maximum downgradient distance	400 ft (120 m)	500 ft (150 m)	500 ft (150 m)
Maximum width	800 ft (240 m)	1800 ft (550 m)	2900 ft (880 m)

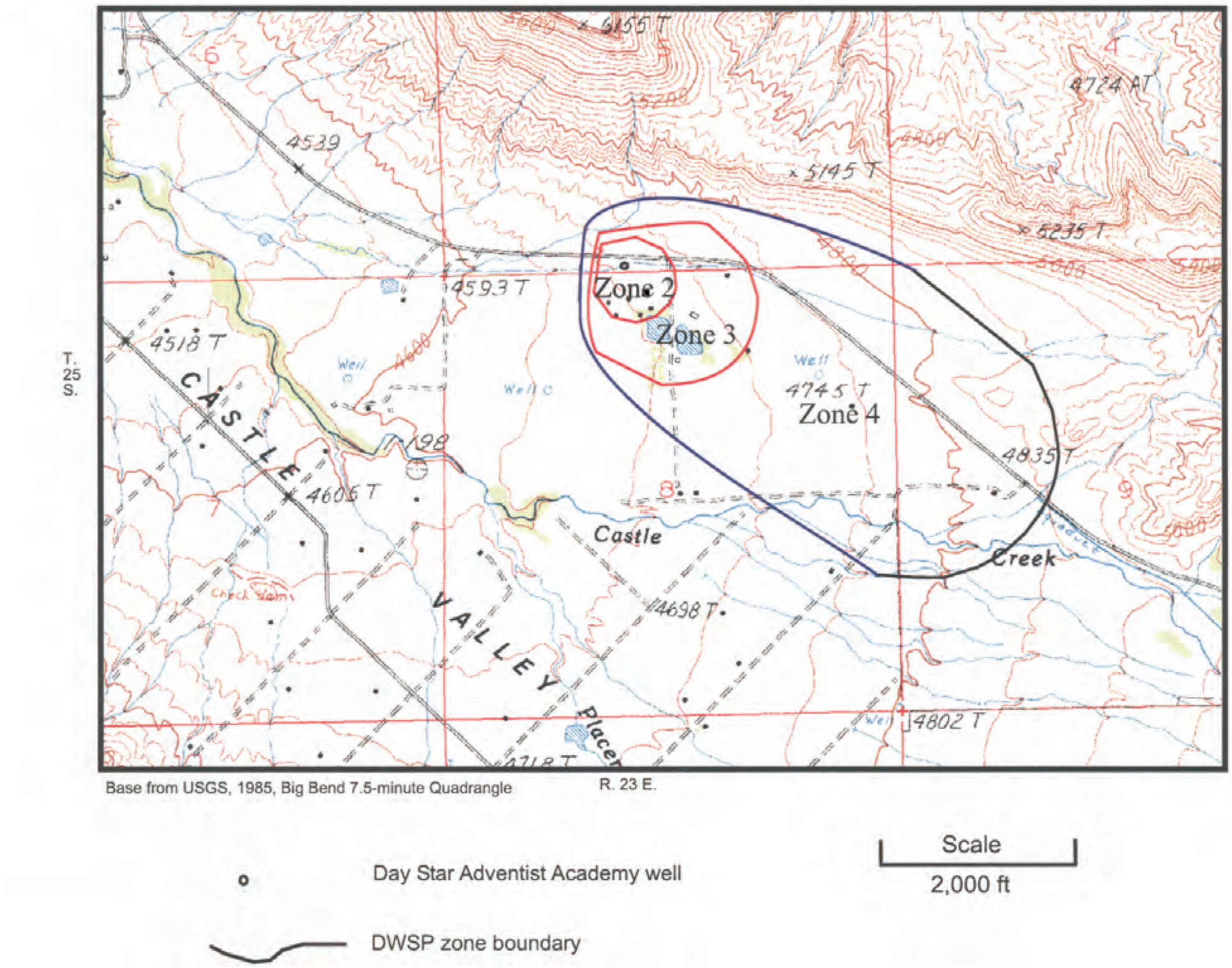

Figure 5. Boundaries of drinking water source protection (DWSP) zones 2, 3, and 4.

SUMMARY AND RECOMMENDATIONS

The Academy public-water-supply well lies on the eastern side of Castle Valley and withdraws ground water from a confined fractured-rock aquifer. Permeability in the aquifer is mostly due to faulting, fracturing, and bedding-plane separations. Recharge to the stratified deposits is from upland areas as subsurface inflow, and by infiltration of stream water that flows across outcrops. The topographic relief and local faulting control ground-water flow through the fractured-rock aquifer in Castle Valley. In the area of the Academy, the valley is relatively flat and hydrostatic heads in the fractured-rock aquifer are above the land surface, producing flowing artesian wells. The hydrogeology of the area is complex, and any WHPA strategy developed and modeling performed must account for the heterogeneous and fractured natured of the aquifer.

I delineated the 250-day, three-year, and 15-year time-related capture zones contributing recharge to the well by applying a semi-analytical model based on estimated effective aquifer properties from an evaluation of the hydrogeology of the area. This approach is a realistic technique for decreasing DWSP zone uncertainty due to the porous media assumption for the purpose of protecting a well. I based my calculations of the DWSP zones on: (1) an artesian aquifer in the area of the Academy; (2) previously determined aquifer properties or conservative estimates of unknown aquifer parameters; (3) the assumption of a single, heterogeneous, anisotropic rock aquifer; (4) the implicit assumption that the potentiometric surface is related to the water table and topography; and (5) the application of ground-water flow travel-time calculations.

Results from the simulation and subsequent particle-tracking analyses indicate time-related capture zones for the well are approximately elongated-oval shaped zones that extend southeastward. The contributing area calculated using the RESSQC module of WHPA includes a substantial part of northeastern Castle Valley. The maximum upgradient distances and width of the protection zone are as follows: 5100 feet (1600 m) upgradient distance and 2900 feet (880 m) wide for zone 4, 1600 feet (490 m) upgradient distance and 1800 feet (550 m) wide for zone 3, and 600 feet (180 m) upgradient distance and 800 feet (240 m) wide for zone 2. Factors influencing the area recharging the well are (1) the hydrogeologic framework of the aquifer system; (2) aquifer transmitting, storage, and yielding properties; (3) discharge from the well; and (4) hydraulic gradient in the aquifer.

In this report I evaluated a part of Castle Valley and used generalized ground-water flow information. Using conservative (protective) parameters in this semi-analytical technique provided large reliable protection zones. Reducing the size of the protection zones would require the collection of additional detailed hydrology data. For a small water system, like the Day Star Adventist Academy water system, the costs associated with developing a DWSP plan for larger DWSP zones may be small compared to the cost of a more detailed hydrologic study. The conceptual understanding of ground-water flow in the fractured-rock aquifer is based on limited information. The DWSP zones should be redelineated if a more detailed hydrologic study is completed for the fractured-rock aquifer, or if the ground-water-flow system deviates significantly from the model used in this report.

ACKNOWLEDGMENTS

I thank Hugh Hurlow, Janae Wallace, Lucy Jordan, Mike Lowe, and Robert Ressetar for reviewing this report.

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APPENDICES

APPENDIX A

Drillers' Reports of Wells

Wells drilled in the early- to mid-1950s, within a mile of the Day Star Adventist Academy well

Copied js 3/4/57
Exam. & Recorded mv 11/28/55
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Well No.

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Report No. 11712
Filed July 17 19 55
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Ret'd

Report of Well and Tunnel Driller

STATE OF UTAH

I 63-394

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such reports constitutes a misdemeanor.)

1. Name and address of person, company or corporation boring or drilling well ~~or tunnel~~. (Strike words not needed)
   Mennel Stewart Moab, Utah
2. Name and address of owner of well ~~or tunnel~~ (Strike Words not needed) Archie Sarten Castleton, Utah
3. Source of supply is in Grand County; drainage area (Leave blank); artesian basin (Leave blank)
4. The number of approved application to appropriate water is 26121 (Upper Well) #2
5. Location of well ~~or mouth of tunnel~~ is situated at a point About 200 ft. from the upper corner of his ranch. S. 400' W 300' fr N¼ Cor. Sec. 8, T25S, R23E, SLBM
   (Describe by rectangular co-ordinates or by one course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)
6. Date on which work on well ~~or tunnel~~ (Strike words not needed) was begun April 1, 1955
7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ (Strike words not needed) May 12, 1955
8. Maximum quantity of water measured as flowing, pumped or (Strike words not needed) on completion of well or tunnel in sec. ft. ; or in gals. per minute Date

DETAIL OF COLLECTING WORKS:

9. WELL: It is drilled, dug, flowing or pump well. (Strike words not needed) Temperature of water °F.
   (a) Total depth of well is ft. below ground surface.
   (b) If flowing well, give water pressure (hydrostatic head) above ground surface ft.
   (c) If pump well, give depth from ground surface to water surface before pumping ; during pumping
   (d) Size and kind of casing 20 ft. 15/2 92 ft. 4 in. 12 in. (If only partially cased, give details)
   (e) Depth to water-bearing stratum (If more than one stratum, give depth to each)
   (f) If casing is perforated, give depth from ground surface to perforations
   (g) Log of well Topsoil to 60 ft. 60 ft. 75 red sand 75 to 88 red clay 88 to 150 red sand Cuttler?
   Sarten pulled me off this hole at 150 t. and had me set up on the hole lower. The well was making alittle water at that depth. He put a rotary on I don't know what happened.
   (h) Well was equipped with cap, valve, or (Strike words not needed) to control flow.

(continued on next page)

10. **TUNNEL:** It is timbered, tiled, piped, open, bulkheaded, covered or..
(Strike words not needed)

(a) Dimensions..............; total length.....................; temperature of water...............................°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel..................

(c) Log of tunnel..

11. **GENERAL REMARKS:** (Note any general or detailed information not covered above).

STATE OF UTAH,
COUNTY OF .... } ss.

I, ...Mennel Stewart..., being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

/s/ Mennel Stewart
Driller

Subscribed and sworn to before me this......15thday of......July.................................., 19 ...55.

(SEAL) /s/ Carroll J. Meador

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Exam. & Recorded mv 11/28/55
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Well No.

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Report No. 11713
Filed July 18 1955
Rec. By mv
Ret'd

Report of Well and Tunnel Driller

STATE OF UTAH

(Separate report shall be filed for each well or tunnel) I63 374

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such reports constitutes a misdemeanor.)

1. Name and address of person, company or corporation boring or drilling well ~~or tunnel.~~ (Strike words not needed)

   Mennel Stewart Moab, Utah

2. Name and address of owner of well ~~or tunnel~~ (Strike Words not needed) Archie Sarten Castleton, Utah

3. Source of supply is in Grand County;

   (Leave blank) drainage area; (Leave blank) artesian basin

4. The number of approved application to appropriate water is 26121 (Lower Well) #1

5. Location of well or mouth of tunnel is situated at a point (1) S. 400' W. 100' fr. N¼ Cor. Sec. 8, T25S, R23E, SLM

   (Describe by rectangular co-ordinates or by one course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)

6. Date on which work on well or tunnel was begun (Strike words not needed) May 1, 1955

7. Date on which work on well or tunnel was completed or abandoned (Strike words not needed) May 3, 1955

8. Maximum quantity of water measured as flowing, pumped or (Strike words not needed) on completion of well or tunnel in sec. ft. ; or in gals. per minute Date

DETAIL OF COLLECTING WORKS: (Not completed see log)

9. **WELL:** It is drilled, dug, flowing or pump well. (Strike words not needed) Temperature of water °F.

   (a) Total depth of well is ft. below ground surface.

   (b) If flowing well, give water pressure (hydrostatic head) above ground surface ft.

   (c) If pump well, give depth from ground surface to water surface before pumping ; during pumping

   (d) Size and kind of casing Drove 12 in to 37 ft. (If only partially cased, give details)

   (e) Depth to water-bearing stratum (If more than one stratum, give depth to each)

   (f) If casing is perforated, give depth from ground surface to perforations

   (g) Log of well Red sand to 37 ft. Sarten moved rotary on upper hole and I moved my rig home.

   (h) Well was equipped with cap, valve, or (Strike words not needed) to control flow.

(continued on next page)

10. **TUNNEL:** It is timbered, tiled, piped, open, bulkheaded, covered or..........
(Strike words not needed)

(a) Dimensions..........; total length..........; temperature of water..........°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel..........

(c) Log of tunnel..........

11. **GENERAL REMARKS:** (Note any general or detailed information not covered above).

STATE OF UTAH,
COUNTY OF .... } ss.

I, Mennel Stewart, being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

/s/ Mennel Stewart
Driller

Subscribed and sworn to before me this 15th day of July, 19 55

(SEAL) /s/ Carroll J. Meador

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Exam. for filing
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Well No.

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Report No. 12313
Filed 7-9 19 56
Rec. By mv
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Report of Well and Tunnel Driller

STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such reports constitutes a misdemeanor.)

1. Name and address o~~f person~~, company ~~or corporation boring or drilling~~/deepening well ~~or tunnel~~ (Strike words not needed)
   Swank Drilling Exploration Co. Moab, Utah
2. Name and address of owner of well ~~or tunnel~~ (Strike Words not needed) Archie Sarten Price, Utah
3. Source of supply is in Grand County;
   (Leave blank) drainage area; (Leave blank) artesian basin
4. The number of approved application to appropriate water is 26121 #3
5. Location of well ~~or mouth of tunnel~~ is situated at a point S. 165 ft. and W. 45 ft. from N¼ Cor. Sec. 8 in T25S, R23E
   (Describe by rectangular co-ordinates or by one course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)
6. Date on which work on well ~~or tunnel~~ was begun (Strike words not needed) 5-24, 1956
7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ (Strike words not needed) 6,1, 1956
8. Maximum quantity of water measured as flowing, ~~pumped or~~ (Strike words not needed) Appx. 200GPM on completion of well ~~or tunnel in sec.-ft~~; or in gals. per minute 200 Date 6,5,-1956

DETAIL OF COLLECTING WORKS:

9. WELL: It is drilled, ~~dug~~, flowing ~~or pump~~ well. (Strike words not needed) Temperature of water real cool °F.
   (a) Total depth of well is 290 ft. below ground surface.
   (b) If flowing well, give water pressure (hydrostatic head) above ground surface ft.
   (c) If pump well, give depth from ground surface to water surface before pumping ; during pumping
   (d) Size and kind of casing 2 In. steel (If only partially cased, give details)
   (e) Depth to water-bearing stratum 285 ft. (If more than one stratum, give depth to each)
   (f) If casing is perforated, give depth from ground surface to perforations Casing set to appx. 42 feet.
   (g) Log of well First water flow small at 210 to 215. Hard sand above and below flow at 285. The formation all the way was red sandstone and shale, with the last five feet becoming harder. No loss of circulation was encountered, and the possibility of seepage is is very very small. The well had been cased when we took over the drilling to complete the hole.
   (h) Well was equipped with cap, valve, or no to control flow. (Strike words not needed)

(continued on next page)

10. **TUNNEL:** It is timbered, tiled, piped, open, bulkheaded, covered or..
(Strike words not needed)

(a) Dimensions..............; total length....................; temperature of water...............................°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel..................

(c) Log of tunnel...

11. **GENERAL REMARKS:** (Note any general or detailed information not covered above).

STATE OF UTAH, }
COUNTY OF Grand } ss.

I, G. W. Swank, being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

/s/ G. W. Swank
Driller

Subscribed and sworn to before me this 25 day of June, 19 56.

(SEAL) /s/ Peggy Payne
Notary Public

Copied js 3/4/57
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Well No.

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Filed 7-9, 19 56
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Ret'd

Report of Well and Tunnel Driller

STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such reports constitutes a misdemeanor.)

1. Name and address of ~~person,~~ company o~~r corporation boring or drilling~~/deepening Well ~~or tunnel.~~ (Strike words not needed)

   Swank Drilling & Exploration Co.

2. Name and address of owner of well ~~or tunnel~~ Archie Sarten Price, Utah (Strike Words not needed)

3. Source of supply is in Grand County;

   (Leave blank) drainage area; (Leave blank) artesian basin

4. The number of approved application to appropriate water is 26121 #4

5. Location of well ~~or mouth of tunnel~~ is situated at a point S. 100 ft. and W. 75 ft. from N¼ Cor. Sec. 8 in T25S, R23E

   (Describe by rectangular co-ordinates or by one course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)

6. Date on which work on well ~~or tunnel~~ was begun 6, 1, 1956 (Strike words not needed)

7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ 6, 5, 1956 (Strike words not needed)

8. Maximum quantity of water measured as flowing, ~~pumped or~~ on completion of well ~~or tunnel in sec. ft.~~ ; or in gals. per minute 100 Date 6,5,1956 (Strike words not needed)

DETAIL OF COLLECTING WORKS:

9. **WELL:** It is drilled, ~~dug,~~ flowing ~~or pump~~ well. Temperature of water real cool °F. (Strike words not needed)

   (a) Total depth of well is 301 ft. below ground surface.

   (b) If flowing well, give water pressure (hydrostatic head) above ground surface ft.

   (c) If pump well, give depth from ground surface to water surface before pumping ; during pumping

   (d) Size and kind of casing 12 inch steel (If only partially cased, give details)

   (e) Depth to water-bearing stratum 300 (If more than one stratum, give depth to each)

   (f) If casing is perforated, give depth from ground surface to perforations
   Casing set at appx. 42 ft.

   (g) Log of well First water flow small at 240 ft. Good flow at 300 ft. The fromation through out was red sandstone and some shale inter mixed. The bottom five or six feet was the same only a harder formation. We encountered no circulation trouble, and the possibility os internal seepage is very very remote. The well had been cased when we took over the drilling.

   (h) Well was equipped with cap, valve, or no to control flow. (Strike words not needed)

(continued on next page)

10. **TUNNEL:** It is timbered, tiled, piped, open, bulkheaded, covered or..........
(Strike words not needed)

(a) Dimensions..........; total length..........; temperature of water..........°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel..........

(c) Log of tunnel..........

11. **GENERAL REMARKS:** (Note any general or detailed information not covered above).

STATE OF UTAH,
COUNTY OF Grand } ss.

I, G. W. Swank, being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

/s/ G. W. Swank
Driller

Subscribed and sworn to before me this 25 day of June, 19 56.

(SEAL) /s/ Peggy Payne

PHOTOSTATED 7-1-58
[redacted]
Exam. & Recorded JJ 8-15-57
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Well No. (D-25-23)8 bаа-1

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Report No. 12944
Filed 7-31-1957
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Ret'd

Report of Well and Tunnel Driller

STATE OF UTAH

A26121

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION: J-63 394 Jobbed

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such reports constitutes a misdemeanor.)

1. Name and address of ~~person~~, ~~company~~ or corporation ~~boring or~~ drilling replacement well or ~~tunnel~~. (Strike words not needed)
   Swank Drilling & Exp cs

2. Name and address of owner of well ~~or tunnel~~. (Strike Words not needed)
   archie Saiter, Price, Utah

3. Source of supply is in Grand County;
   drainage area; (Leave blank) (Leave blank) artesian basin replacement for well #3

4. The number of approved application to appropriate water is A 26121 S 177

5. Location of well or ~~mouth of tunnel~~ is situated at a point ~~#2~~ State 565 + W 45 ft from N ¼ Cor Sec 8-T.25 South R.23 East
   (Describe by rectangular co-ordinates or by one course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)

6. Date on which work on well ~~or tunnel~~ was begun June 28-57 (Strike words not needed)

7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ July 25-57 (Strike words not needed)

8. Maximum quantity of water measured as flowing, pumped or Not measured on completion of well ~~or tunnel~~ in sec. ft.; or in gals. per minute aprox 150 gal Date 7-25-57 (Strike words not needed)

DETAIL OF COLLECTING WORKS:

9. **WELL:** It is drilled, ~~dug~~, flowing or ~~pump~~ well. Temperature of water °F. (Strike words not needed)
   (a) Total depth of well is 298 ft. below ground surface.
   (b) If flowing well, give water pressure (hydrostatic head) above ground surface 15 lbs ft. aprox
   (c) If pump well, give depth from ground surface to water surface before pumping; during pumping
   (d) Size and kind of casing 6" continuo weld new pipe (If only partially cased, give details)
   (e) Depth to water-bearing stratum 280' (If more than one stratum, give depth to each)
   (f) If casing is perforated, give depth from ground surface to perforations
   casing set at 280' cemented at 280'-25 sa of cement
   (g) Log of well
   Rework on well #
   (h) Well was equipped with cap, valve, or to control flow. (Strike words not needed)

(continued on next page)

10. **TUNNEL:** It is timbered, tiled, piped, open, bulkheaded, covered or...
(Strike words not needed)

(a) Dimensions..............; total length....................; temperature of water..............................°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel..................

(c) Log of tunnel...

11. **GENERAL REMARKS:** (Note any general or detailed information not covered above).

Well # was drilled to top of water Bearing sand & cemented w/25 sax of Cement & 4% Jel cemented from bottom rock to 160 ft.

RECEIVED JUL 31 1957 STATE ENGINEER COUNTER

STATE OF UTAH,
COUNTY OF Salt Lake } ss.

I, G. W. Swant, being first duly sworn,

do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

G W Swant
Driller

Subscribed and sworn to before me this 31st day of July, 19 57

(SEAL) Norma Nelson

PHOTOSTATED 7-8-58
[illegible]
Exam. & Recorded JS 8-15-57
Exam. for filing
Final Copy checked
Indexed 4-18-58
Well No. (D-25-23)8

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Report No. 12945
Filed 7-31, 19 57
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Report of Well and Tunnel Driller

STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION: 162-396 Lobbed

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such reports constitutes a misdemeanor.)

1. Name and address of ~~person~~, company ~~or corporation boring or~~ drilling well ~~or tunnel~~. (Strike words not needed)
   Swank Drilling & Exp Co
2. Name and address of owner of well ~~or tunnel~~ (Strike Words not needed)
   archie Sorten Price, utah
3. Source of supply is in Grand County;
   drainage area; (Leave blank) artesian basin (Leave blank) replacement for well #1
4. The number of approved application to appropriate water is A 26121
5. Location of well ~~or mouth of tunnel~~ is situated at a point 5.961' W - 67' from N ¼ Cor Sec 8 T 25 S, Range 23E
   (Describe by rectangular co-ordinates or by one course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)
6. Date on which work on well ~~or tunnel~~ was begun (Strike words not needed)
7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ (Strike words not needed)
8. Maximum quantity of water measured as flowing, ~~pumped~~ or aprox 175 on completion of well ~~or tunnel~~ in sec. ft.; or in gals. per minute Date 6-25-57 (Strike words not needed)

DETAIL OF COLLECTING WORKS:

9. **WELL:** It is drilled, ~~dug~~, flowing or ~~pump~~ well. Temperature of water ? °F. (Strike words not needed)
   (a) Total depth of well is 308 ft. below ground surface.
   (b) If flowing well, give water pressure (hydrostatic head) above ground surface 15 lbs ft.
   (c) If pump well, give depth from ground surface to water surface before pumping ; during pumping
   (d) Size and kind of casing 6" continuos weld (If only partially cased, give details)
   (e) Depth to water-bearing stratum 301 to 308 (If more than one stratum, give depth to each)
   (f) If casing is perforated, give depth from ground surface to perforations no
   Set at 301
   (g) Log of well Rework on Well #1
   (h) Well was equipped with cap, ~~valve~~, or to control flow. (Strike words not needed)

(continued on next page)

10. **TUNNEL:** It is timbered, tiled, piped, open, bulkheaded, covered or ....
(Strike words not needed)

(a) Dimensions ....; total length ....; temperature of water .... °F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel ....

(c) Log of tunnel ....

11. **GENERAL REMARKS:** (Note any general or detailed information not covered above).

Well #1 Drilled to top of Water Bear Sand at 301' - 6" welded casing set at 301' cemented from bottom Back above 1st water at 240' used 25 sax cement and 4% gel.

RECEIVED JUL 31 1957 STATE ENGINEER COUNTER

STATE OF UTAH,
COUNTY OF Salt Lake } ss.

I, G. W. Swank, being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

G. W. Swank
Driller

Subscribed and sworn to before me this 31st day of July, 1957.

(SEAL) Norma Nelson
Notary Public

APPENDIX B

Problem Summaries and WHPA Printouts Using RESSQC Module

RESSQC PROBLEM SUMMARY

Simulation Option:	capture zones
Number of Pumping Wells:	1
Number of Recharge Wells:	0
Transmissivity:	1000. ft**2/d
Hydraulic Gradient:	0.008000 ft/ft
Angle of Ambient Flow:	150.00 degrees
Aquifer Porosity:	0.15 dimensionless
Aquifer Thickness:	80. ft
Simulation Time:	5435. days
No. of Capture Zone Times:	3

PUMPING WELL #1 PARAMETERS

X Coordinate:	194874. ft
Y Coordinate:	1304291. ft
Well Discharge Rate:	38600. ft**3/d
Number of Pathlines:	10
Pathline Plotting Interval:	1

RESSQC.OUT FOR DAY STAR ADEVENTIST ACADEMY

FT AND DA SYSTEM OF UNITS IS USED

REGIONAL FLOW, PORE VELOCITY	=	0.67 FT/DAY
ORIENTATION OF REGIONAL FLOW	=	150.00 DEGREES
THICKNESS OF THE AQUIFER	=	80.00 FEET
POROSIT	=	15.00 PERCENT
PERIOD STUDIED	=	5435.00 DAYS
INITIAL AQUIFER CONCENTRATION	=	0.000E 01
DEFAULT INJECTION CONCENTRATION	=	0.000E 01
STREAMLINE STEP LENGTH	=	10.00 FEET
ADSORPTION CAPACITY OF ROCK	=	00.00 PERCENT

3 FRONTS ARE PLOTTED AT 2.50E+02 DAYS 1.09E+03 DAYS 5.43E+03 DAYS

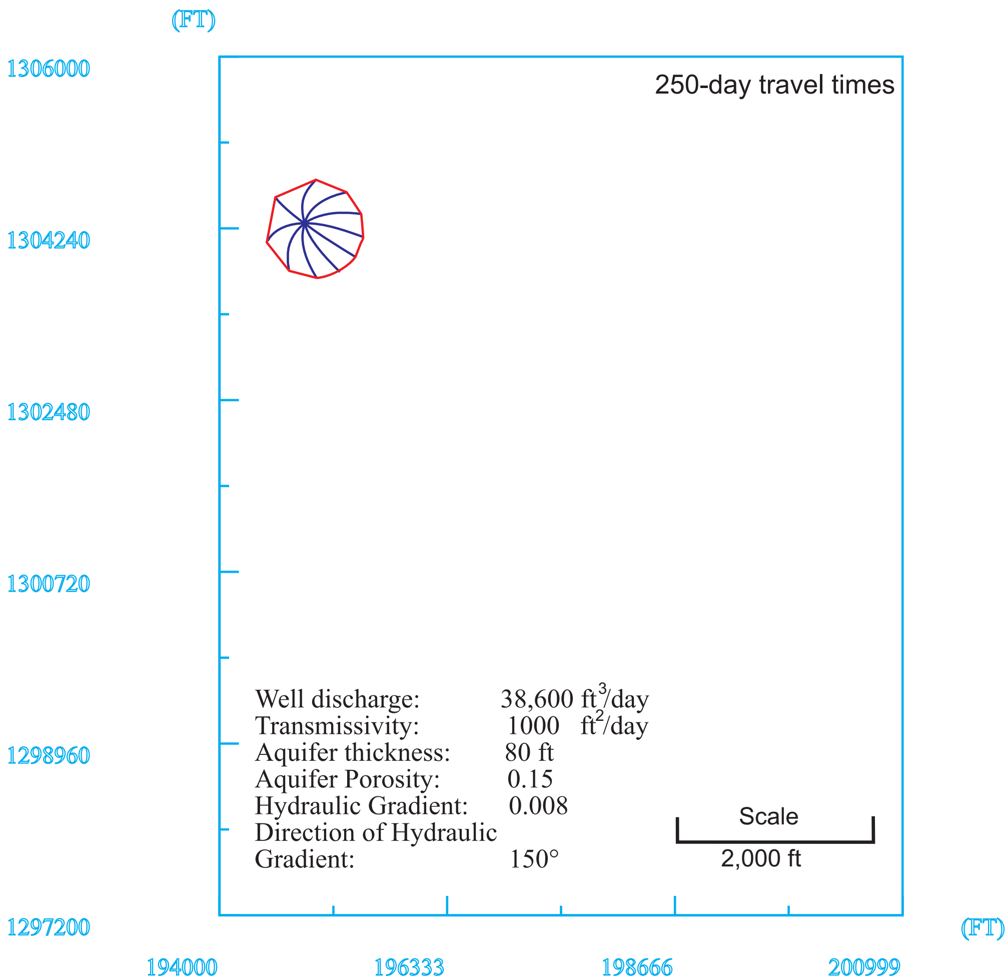
NUMBER OF INJECTION WELLS = 0
NUMBER OF PUMPING WELLS = 1

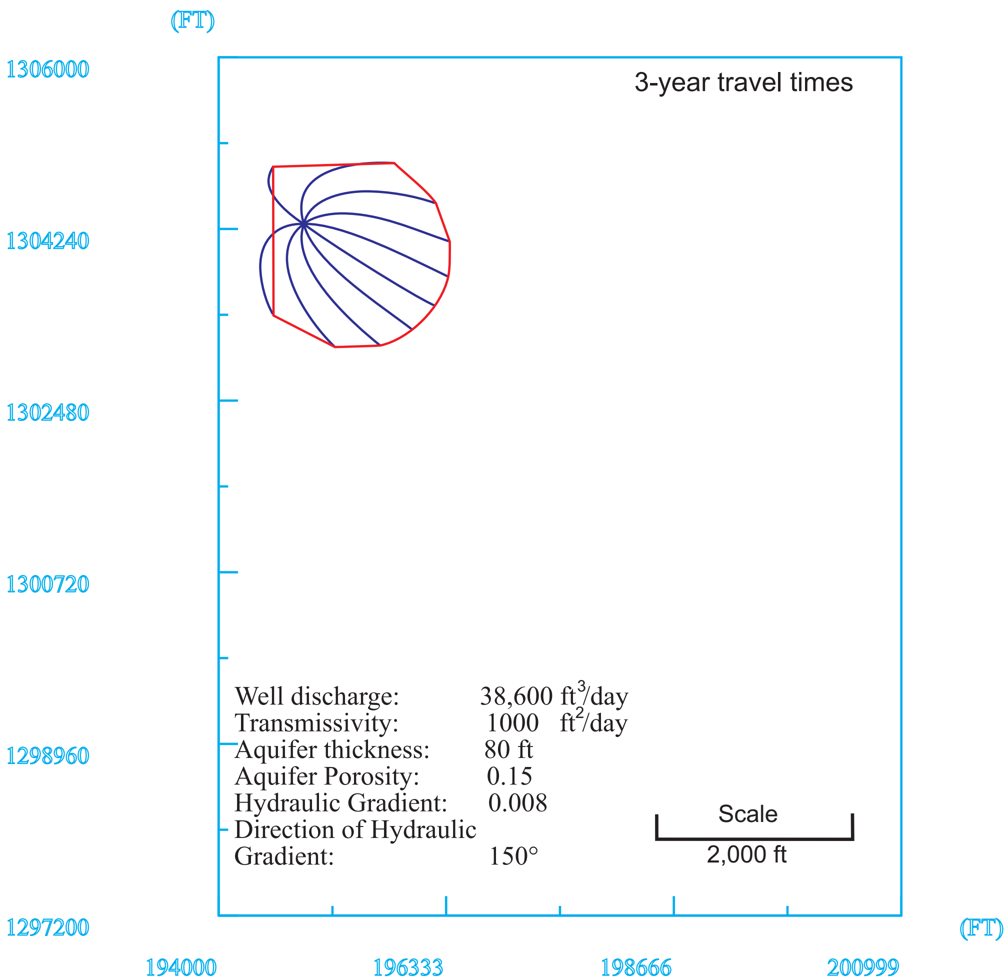
1 1 PRODUCTION WELLS

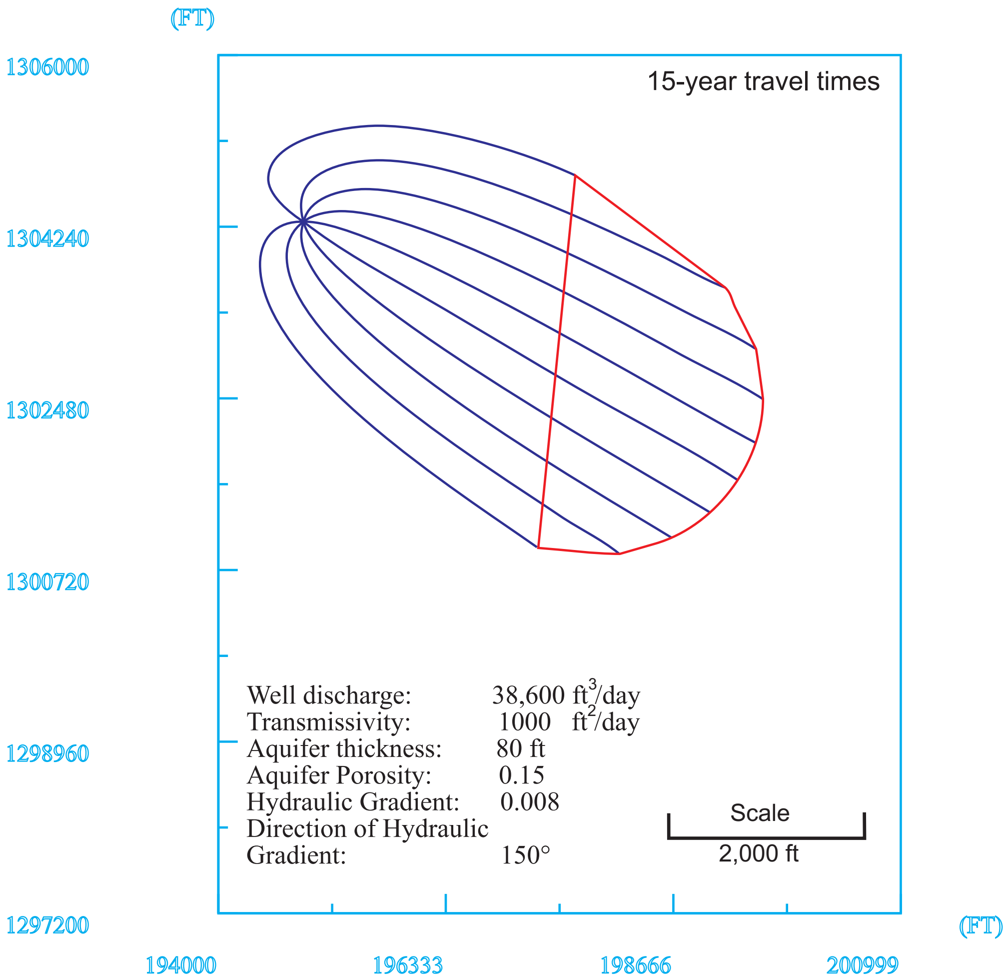
WELL NAME	X FEET	Y FEET	FLOW-RATE FT3/DAY	RADIUS FEET	INDICATOR
1	194873.91	1304291.00	38600.00	5.00E 01	0

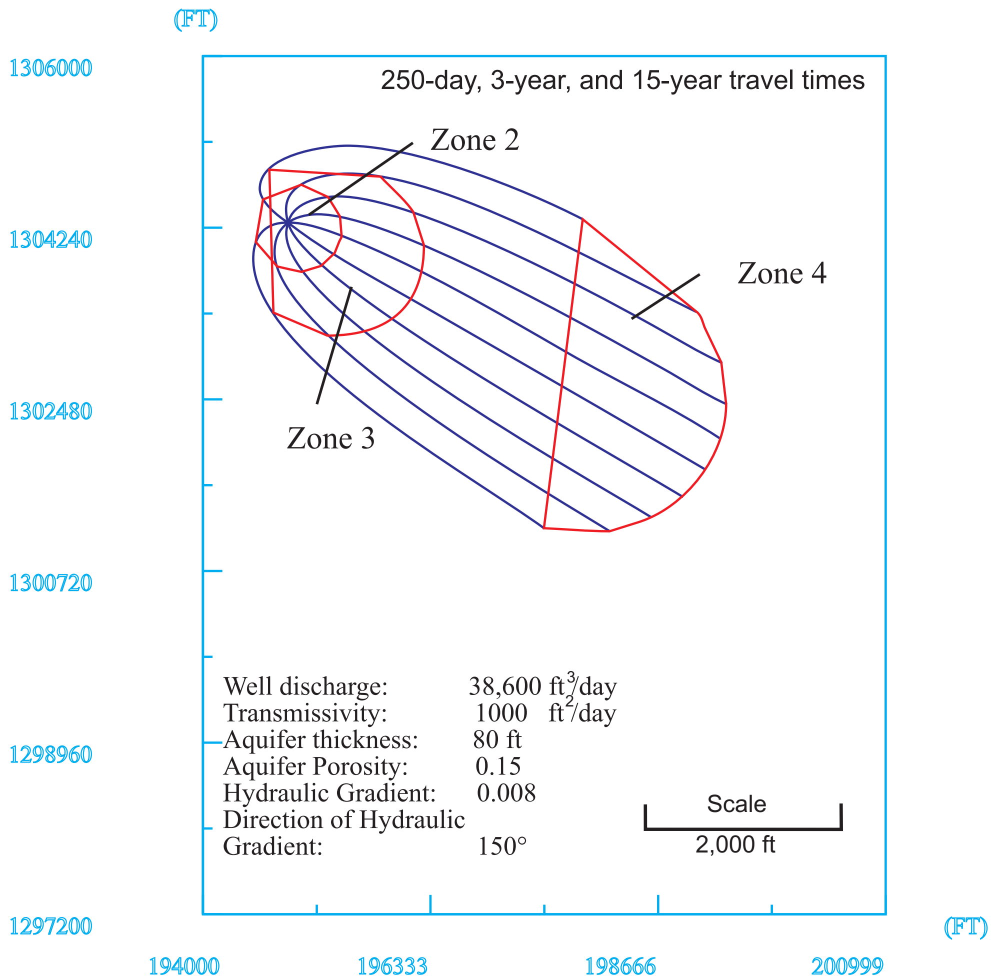
STREAMLINES DEPARTING FROM INJECTION WELL

NUMBER OF STREAMLINE	WELL REACHED	TIME OF ARRIVAL	ANGLE BETA IN DEGREES
1	+++NONE+++	5443.8 DAYS	0.0
2	+++NONE+++	5439.9 DAYS	36.0
3	+++NONE+++	5444.4 DAYS	72.0
4	+++NONE+++	5442.7 DAYS	108.0
5	+++NONE+++	5441.8 DAY	144.0
6	+++NONE+++	5446.4 DAYS	180.0
7	+++NONE+++	5442.0 DAYS	216.0
8	+++NONE+++	5440.4 DAYS	252.0
9	+++NONE+++	5435.4 DAYS	288.0
10	+++NONE+++	5439.2 DAYS	324.0


(FT)
1306000
1304240
1302480
1300720
1298960
1297200
250-day travel times
Well discharge: 38,600 ft3/day
Transmissivity: 1000 ft2/day
Aquifer thickness: 80 ft
Aquifer Porosity: 0.15
Hydraulic Gradient: 0.008
Direction of Hydraulic Gradient: 150°
Scale
2,000 ft
(FT)
194000
196333
198666
200999


(FT)
1306000
1304240
1302480
1300720
1298960
1297200
194000
196333
198666
200999
(FT)
3-year travel times
Well discharge: 38,600 ft3/day
Transmissivity: 1000 ft2/day
Aquifer thickness: 80 ft
Aquifer Porosity: 0.15
Hydraulic Gradient: 0.008
Direction of Hydraulic Gradient: 150°
Scale
2,000 ft


(FT)
1306000
1304240
1302480
1300720
1298960
1297200
194000
196333
198666
200999
(FT)
15-year travel times
Well discharge: 38,600 ft³/day
Transmissivity: 1000 ft²/day
Aquifer thickness: 80 ft
Aquifer Porosity: 0.15
Hydraulic Gradient: 0.008
Direction of Hydraulic Gradient: 150°
Scale
2,000 ft



(FT)
1306000
1304240
1302480
1300720
1298960
1297200
194000
196333
198666
200999
(FT)
250-day, 3-year, and 15-year travel times
Zone 2
Zone 3
Zone 4
Well discharge: 38,600 ft3/day
Transmissivity: 1000 ft2/day
Aquifer thickness: 80 ft
Aquifer Porosity: 0.15
Hydraulic Gradient: 0.008
Direction of Hydraulic Gradient: 150°
Scale
2,000 ft